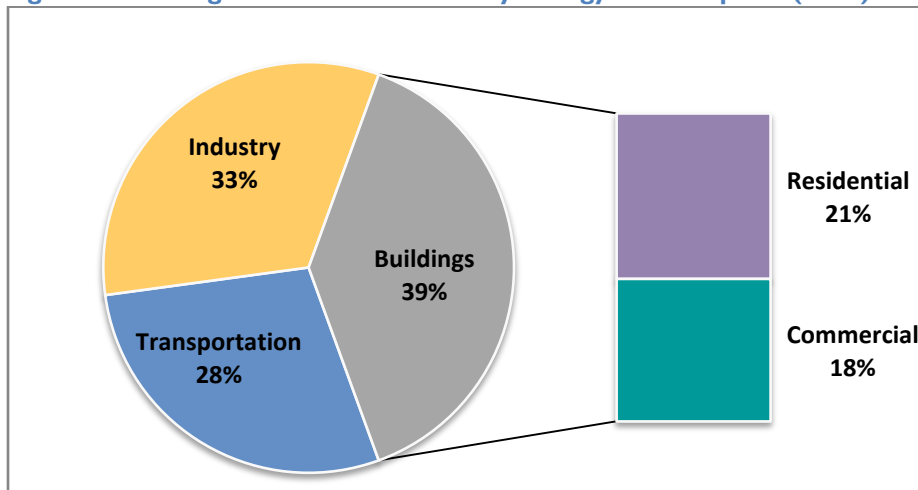


## Buildings and Emissions: Making the Connection

Residential and commercial buildings account for almost 39 percent of total U.S. energy consumption and 38 percent of U.S. carbon dioxide (CO<sub>2</sub>) emissions.<sup>1</sup> Nearly all of the greenhouse gas (GHG) emissions from the residential and commercial sectors can be attributed to energy use in buildings (see [CLIMATE TECHBOOK: Residential and Commercial Sectors Overview](#)).

Figure 1: Buildings Share of U.S. Primary Energy Consumption (2006)



Source: U.S. Department of Energy (DOE), [2008 Buildings Energy Data Book](#), Section 1.1.1, 2008.

GHG emissions from energy use in buildings can be broken down into two types: first, direct emissions from the on-site combustion of fuels for heating and cooking and, second, emissions from the end use of electricity used to heat, cool, and provide power to buildings. Emission reductions from buildings can be achieved by reducing emissions from the energy supply (see [CLIMATE TECHBOOK: Electricity Sector Overview](#), as well as the individual *CLIMATE TECHBOOK* briefs on low- and zero-emission energy supply technologies) or by reducing energy consumption through improved building design, increased energy efficiency and conservation, and other mechanisms that reduce energy demand in buildings (see [CLIMATE TECHBOOK: Building Envelope](#)).

## Factors Affecting Building-Related Emissions

Buildings come in a wide variety of shapes, sizes, and purposes, and they have been built at different times according to different standards. Consequently, addressing energy use in any given building requires a holistic approach to ensure the best results. In considering buildings generally, the following elements play important roles in shaping energy consumption and use. Whole-building design standards include most or all of these categories in order to maximize energy savings, but frequently any adjustments in these areas can be beneficial.

- **Embodied energy**  
*Embodied energy* refers to the energy required to extract, manufacture, transport, install, and dispose of building materials. The GHG emissions associated with the embodied energy of a building are not attributed to “buildings” in above values, but efforts to reduce this energy use and

associated emissions, for example through the substitution of bio-based products, can be made as part of a larger effort to reduce emissions from buildings.

- **Building design**

Overall building design can help determine the amount of lighting, heating, and cooling a building will require. Architects and engineers have developed innovative new ways to improve overall building design in order to maximize light and heat efficiency.<sup>2</sup> Another important determinant of energy consumption is size because larger buildings generally require more energy for heating, cooling, and lighting. The United States has seen a general trend of increased building size among residential buildings.

- **Building envelope**

The building envelope is the interface between the interior of a building and the outdoor environment. Minimizing heat transfer through the building envelope is crucial for reducing the need for space heating or cooling. Insulation, air sealing, and windows can each play an important role in minimizing heat transfer. For more information, see *CLIMATE TECHBOOK: Building Envelope*.

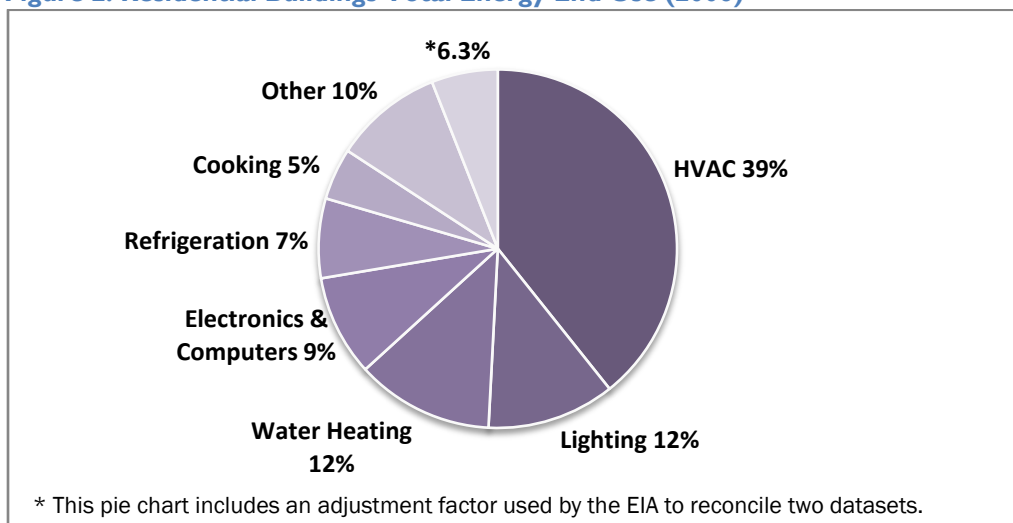
- **On-site or distributed generation**

The terms “on-site generation” or “distributed generation” refer to energy that is produced at the point of use and encompass many different options from both renewable and fossil fuel sources, as well as small energy storage systems. Many buildings can integrate distributed generation as either an alternative or supplement to grid-supplied electricity.

- **Energy end uses in buildings**

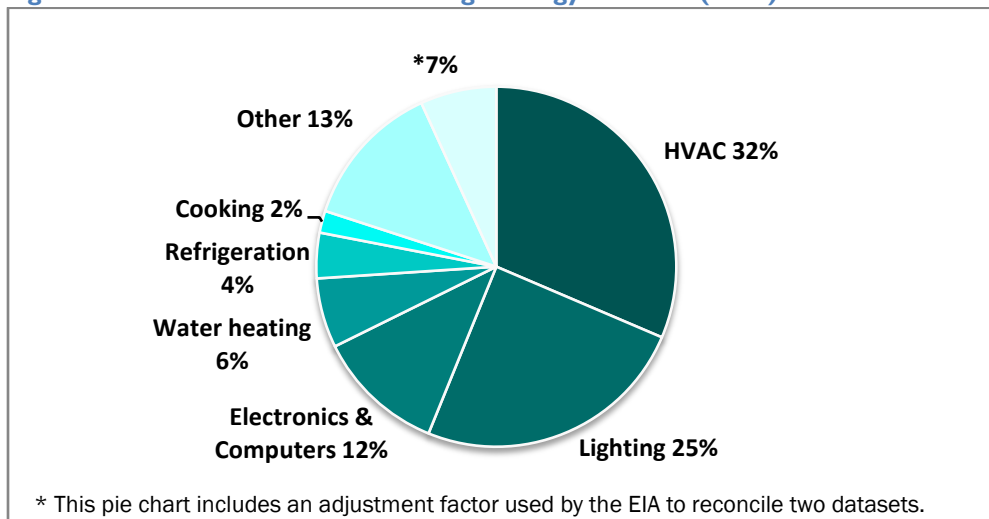
Utilizing efficient technologies can reduce GHG emissions by moderating energy use. In both residential and commercial buildings, energy consumption is dominated by space heating, cooling, and air conditioning (HVAC) and lighting (see Figure 2 and DOE, [2008 Buildings Energy Databook](#), Section 2.1.5, 2008). In addition to reducing energy use and associated GHG emissions, energy efficiency improvements also yield a variety of co-benefits, including lower monthly utility bills and greater energy security.<sup>3</sup>

**Figure 2: Residential Buildings Total Energy End Use (2006)**



Source: DOE, [2008 Buildings Energy Data Book](#), Section 2.1.5, 2008.

Figure 3: Commercial Sector Buildings Energy End Use (2006)



Source: DOE, [2008 Buildings Energy Data Book](#), Section 3.1.4, 2008.

- Space heating, cooling, and air conditioning (HVAC)**  
 Opportunities for minimizing HVAC-related energy losses include making use of natural ventilation and natural sources of heat, minimizing unwanted heat and humidity gains from lights and appliances, minimizing energy losses in conventional systems by upgrading equipment or downsizing the scale of the equipment, and integrating new efficient technologies such as evaporative coolers and ductless systems. Adjustments to HVAC systems can occur and be most effective with modifications in other building elements. For example, increasing window performance and the insulating properties of the building envelope will reduce the demands upon the HVAC system and will allow HVAC equipment to be downsized, enabling efficiency improvements and cost savings.
- Lighting**  
 Energy use for lighting can be reduced in two ways: reducing the amount of artificial light required and using more efficient technology. Reducing light use can be achieved by behavioral changes—individual commitments to only keeping on the lights that are in use—or by using motion sensors, occupancy sensors, time sensors, and photosensors to automatically ensure that lights are only on when they are in use. Options for using more efficient technology include changing light bulbs and lighting fixtures from incandescent bulbs to fluorescents or solid-state lighting options.

### **Emission Reduction Potential of Climate-Friendly Buildings**

Reductions in building-related GHG emissions can be achieved in many different ways: by increasing the amount of electricity generated from low- and zero-carbon technologies, by retrofitting existing buildings to reduce energy consumption and improve energy efficiency, and by constructing new buildings to be low- or zero-energy buildings. Many factors influence the level of emission reductions achieved. Significant improvements in energy efficiency are attainable and can reduce building-related emissions to very low levels or, when coupled with renewable energy sources, to zero.

Zero-energy buildings (ZEBs) are buildings designed to have markedly reduced energy needs achieved through design and efficiency measures; the remaining energy needs required by these buildings can be achieved through renewable technologies. ZEBs can be net energy producers through the use of on-site

renewables. The Energy Independence and Security Act of 2007 (EISA 2007) directed the U.S. Department of Energy to form the Net-Zero Energy Commercial Building Initiative, a public-private collaboration, in order to “develop and disseminate technologies, practices, and policies” to promote and facilitate the transition to zero net energy commercial buildings. EISA 2007 calls for all new commercial buildings to be zero net energy consumers by 2030 and all U.S. commercial buildings to be zero net energy consumers by 2050.<sup>4</sup> A recent analysis showed that by using existing technologies and practices, 22 percent of commercial buildings could be ZEBs by 2025; this number increases to 64 percent if technology improvements are included.<sup>5</sup>

A variety of other public and private efforts to reduce energy consumption and GHG emissions from commercial and residential buildings have emerged in recent years, including the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) rating system, Architecture 2030’s 2030 Challenge, and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers’ (ASHRAE) goal to improve commercial building codes by 30 percent by 2010.<sup>6</sup>

### Obstacles to Climate-Friendly Buildings

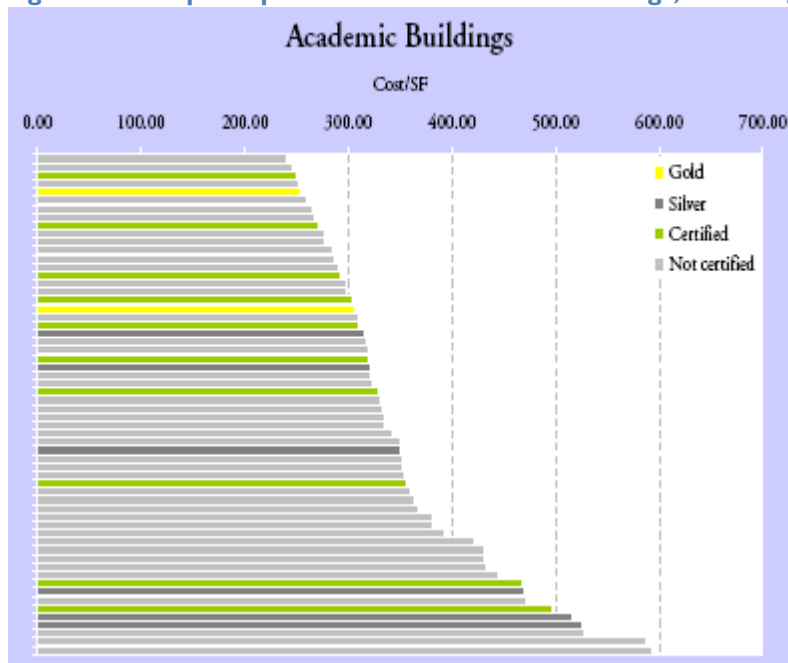
Building-related GHGs can be reduced in many ways, and these different pathways to lower emissions can also face a number of challenges. In broad terms, these obstacles include:

- **Cost concerns**

Estimates vary as to the financial cost and emissions-reducing potential for green building and energy efficient building practices, particularly because of the range of ideas and products and the degree to which specific technologies and designs are utilized. In many cases, the integration of efficient practices can reduce energy use in multiple elements of the building; for example, insulation and solar heating can reduce HVAC equipment costs and electricity costs, and strategic design can reduce the need for artificial lighting as well as improve air circulation.

New efficient buildings are estimated to have costs equal to or only slightly more than those for conventional buildings. For new buildings, it is estimated that the additional cost of state-of-the art, energy-efficient technology is less than 2 percent of the total building cost.<sup>7</sup> For example, a 2006 study comparing the cost of LEED-certified buildings compared with the cost of non-certified buildings<sup>8</sup> found that LEED-certification is not a strong indicator of cost. Academic buildings with and without LEED certification can incur a wide range of costs on a square footage basis (see Figure 4).

Figure 4: Cost per Square Foot of Academic Buildings, Including LEED- and Non-certified Buildings



Source: Langdon, D., *The Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption*, 2007.

Regardless of initial cost, efficient buildings can yield savings over the lifetime of the building through:

- Reduced utility bills; average energy costs for high-performance buildings are 50 percent less than for comparable, conventionally designed buildings.<sup>9</sup>
- Increased property value.<sup>10</sup>

- **Market barriers**

A variety of market barriers exist, including the “split incentive” barrier wherein there exists a disconnect between those that manage the building and those who must pay the utility bills. Thirty-two percent of households and 40 percent of commercial buildings are rented or leased; in these cases, tenants do not have much control over retrofits or building improvements, and landlords may not reap the benefits of more efficient technology.<sup>11</sup>

In addition, the prevailing fee structures for building design engineers cause first costs to be emphasized over life-cycle costs. Projects are often awarded in the first place to the team that designs the building that costs the least to construct; their fees are typically reduced if actual construction costs exceed the estimated costs.<sup>12</sup> This practice tends to hinder energy efficiency because initial capital costs are typically higher for the installation of superior heating, ventilation, and air-conditioning systems that reduce subsequent operating costs.

- **Public policy and planning barriers**

Policies and planning efforts that affect buildings are often implemented at the state or local level. Policies can be designed to encourage more climate-friendly buildings, but a variety of policies also exist that discourage making buildings more climate-friendly. For example, many utilities have

incentives to generate and sell more electricity and little or no incentive to encourage energy efficiency, even if the energy efficiency options have lower costs.

- **Customer barriers**

Lack of information about energy-saving opportunities and incentives, such as rebates and low-interest loans, can result in consumer underinvestment. In addition, lack of access to energy-efficient technologies (e.g., because a particular technology is not stocked in local stores) can limit the use of some technologies. Understanding these barriers may improve the feasibility of efficient construction and planning. With increasing availability of efficient technology and the growing popularity of green building techniques, it is becoming more and more important to address these barriers to the implementation of efficient and effective building technology.

### Policy Options to Promote Climate-Friendly Buildings

The mosaic of current policies affecting the building sector is complex and dynamic involving voluntary and mandatory programs implemented at all levels of government, from local to federal. Government efforts to reduce the overall environmental impact of buildings have resulted in numerous innovative policies at the state and local levels. Non-governmental organizations, utilities, and other private actors also play a role in shaping GHG emissions from buildings through third-party “green building” certification, energy efficiency programs, and other efforts.

Various taxonomies have been used to describe the policy instruments that govern buildings, typically distinguishing between regulations, financial incentives, information and education, management of government energy use, and subsidies for research and development (R&D). Each of these is broadly described below.

- **Standards and codes**

Regulatory policies include building and zoning codes, appliance energy efficiency standards, clean energy portfolio standards, and electricity interconnection standards for distributed generation equipment. Building codes can require a minimum level of energy efficiency for new buildings, thus mandating reductions at the construction stage, where there is the most opportunity to integrate efficiency measures. Zoning codes can provide incentives to developers to achieve higher performance. Because of regional differences in such factors as climatic conditions and building practices, and because building and zoning codes are implemented by states and localities, the codes vary considerably across the country. While substantial progress has been made over the past decade, opportunities to strengthen code requirements and compliance remain.

Appliance and equipment standards require minimum efficiencies to be met by all regulated products sold; they thereby eliminate the least efficient products from the market. Federal standards exist for many residential and commercial appliances, and several states have implemented standards for appliances not covered by federal standards (see [Appliance Efficiency Standards](#)).

- **Financial incentives**

Financial incentives can best induce energy-efficient behavior where relatively few barriers limit information and decision-making opportunities (e.g., in owner-occupied buildings). Financial incentives include tax credits, rebates, low-interest loans, energy-efficient mortgages, and innovative financing, all of which address the barrier of first costs. Many utilities also offer individual incentive programs, because reducing demand, especially peak demand, can enhance the utility’s system-wide performance.

- **Information and education**

While many businesses and homeowners express interest in making energy-efficiency improvements for their own buildings and homes, they often do not know which products or services to ask for, who supplies them in their areas, or whether the energy savings realized will live up to claims. Requiring providers to furnish good information to consumers on the performance of appliances, equipment and even entire buildings is a powerful tool for promoting energy efficiency by enabling intelligent consumer choices.

- **Lead-by-example programs**

A variety of mechanisms are available to ensure that government agencies lead by example in the effort to build and manage more energy-efficient buildings and reduce GHG emissions. For example, several cities and states, and federal agencies (including the General Services Administration), have mandated LEED or LEED-equivalent certification for public buildings, and the Energy Independence and Security Act of 2007 includes provisions for reduced energy use and energy efficiency improvements in federal buildings.

- **Research and development (R&D)**

In the long run, the opportunities for a low-greenhouse gas energy future depend critically on new and emerging technologies. Some technological improvements are incremental and have a high probability of commercial introduction over the next decade (such as low-cost compact fluorescents). Other technology advances will require considerable R&D before they can become commercially feasible (such as solid-state lighting). The fragmented and highly competitive market structure of the building sector and the small size of most building companies discourage private R&D, on both individual components and the interactive performance of components in whole buildings.

- *Building Technologies Center*

The Oak Ridge National Laboratory's Buildings Technology Center was established by the U.S. Department of Energy (DOE) and performs research into issues including heating and cooling equipment, thermal engineering, weatherization, building design and performance, envelope systems and materials, and power systems.

- *Emerging Technologies*

This U.S. DOE-sponsored program develops technology that would reduce energy use in residential and commercial buildings by 60-70 percent. Technologies are in fields including solid-state lighting, space conditioning and refrigeration, building envelopes, and analysis tools and design strategies that would facilitate the development of energy efficient buildings through software and computer-based building analysis.

### Related Pew Center Resources

CLIMATE TECHBOOK: *Building Envelope*, 2009

<http://www.pewclimate.org/technology/factsheet/BuildingEnvelope>

CLIMATE TECHBOOK: *Residential and Commercial Sectors Overview*, 2009

<http://www.pewclimate.org/technology/overview/res-comm>

*Building Solutions to Climate Change*, 2006

[http://www.pewclimate.org/policy\\_center/policy\\_reports\\_and\\_analysis/buildings/](http://www.pewclimate.org/policy_center/policy_reports_and_analysis/buildings/)

MAP: Commercial Building Energy Codes

[http://www.pewclimate.org/what\\_s\\_being\\_done/in\\_the\\_states/comm\\_energy\\_codes.cfm](http://www.pewclimate.org/what_s_being_done/in_the_states/comm_energy_codes.cfm)

MAP: Green Building Standards for State Buildings

[http://www.pewclimate.org/what\\_s\\_being\\_done/in\\_the\\_states/leed\\_state\\_buildings.cfm](http://www.pewclimate.org/what_s_being_done/in_the_states/leed_state_buildings.cfm)

MAP: Residential Building Energy Codes

[http://www.pewclimate.org/what\\_s\\_being\\_done/in\\_the\\_states/res\\_energy\\_codes.cfm](http://www.pewclimate.org/what_s_being_done/in_the_states/res_energy_codes.cfm)

*Towards a Climate-Friendly Built Environment*, 2005 [http://www.pewclimate.org/global-warming-in-depth/all\\_reports/buildings](http://www.pewclimate.org/global-warming-in-depth/all_reports/buildings)

### **Further Reading / Additional Resources**

Building Industry Research Alliance <http://www.bira.ws/publications.php>

Commercial Buildings Initiative <http://www.zeroenergycbi.org/index.html>

ENERGY STAR®, Federal Tax Credits for Energy Efficiency, updated 24 April 2009

[http://www.energystar.gov/index.cfm?c=products.pr\\_tax\\_credits](http://www.energystar.gov/index.cfm?c=products.pr_tax_credits)

Martin, R. L., "Home Energy Checklist: Reduce Your Energy Costs," Energy & Environmental Building Association, accessed 11 May 2009 <http://www.eeba.org/resources/publications/hec/index.html>

National Association of Home Builders (NAHB), *NAHB Model Green Home Buildings Guidelines*, 2006 [http://www.nahbgreen.org/content/pdf/nahb\\_guidelines.pdf](http://www.nahbgreen.org/content/pdf/nahb_guidelines.pdf)

*The Potential Impact of Zero-Energy Homes*, prepared for the National Renewable Energy Laboratory by the NAHB Research Center, Inc., 2006 <http://www.toolbase.org/PDF/CaseStudies/ZEHPotentialImpact.pdf>

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy

- *2008 Buildings Energy Data Book*, 2008 <http://buildingsdatabook.eren.doe.gov>
- Building America Best Practices Series and Case Studies [http://www1.eere.energy.gov/buildings/building\\_america/publications.html](http://www1.eere.energy.gov/buildings/building_america/publications.html)
- Building Technologies Program <http://www1.eere.energy.gov/buildings/>

U.S. Green Building Council <http://www.usgbc.org>

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<sup>1</sup> U.S. Department of Energy (DOE). *2008 Buildings Energy Data Book*. Prepared for U.S. Department of Energy Office of Energy Efficiency and Renewable Energy by D&R International, Ltd. Silver Spring, MD. 2008. <http://buildingsdatabook.eren.doe.gov>

<sup>2</sup> The DOE has developed the *Building America Best Practices Series* that includes five climate-specific sets of building best practices that focus on reducing energy use and improving housing durability and comfort. Learn more at [http://www1.eere.energy.gov/buildings/building\\_america/publications.html](http://www1.eere.energy.gov/buildings/building_america/publications.html).

<sup>3</sup> U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy, *National Action Plan for Energy Efficiency*. Washington, DC: EPA, 2006.

<sup>4</sup> DOE, *Net-Zero Energy Commercial Building Initiative*. Updated 27 February 2009. [http://www1.eere.energy.gov/buildings/commercial\\_initiative/goals.html#arrow](http://www1.eere.energy.gov/buildings/commercial_initiative/goals.html#arrow)

<sup>5</sup> Griffith, B., P. Torcellini, and N. Long, *Assessment of the Technical Potential for Achieving Zero-Energy Commercial Buildings*. NREL/CP-550-39830, 2006. <http://www.nrel.gov/docs/fy06osti/39830.pdf>

<sup>6</sup> See *Related Efforts* for a list and links to other programs that support the transition to zero net energy buildings <http://www.zeroenergycbi.org/resources/index.html>.

<sup>7</sup> For more information, see page 33 of *Towards a Climate-Friendly Built Environment*. Prepared for the Pew Center on Global Climate Change by M. Brown, F. Southworth, and T. Stovall, 2005. [http://www.pewclimate.org/global-warming-in-depth/all\\_reports/buildings](http://www.pewclimate.org/global-warming-in-depth/all_reports/buildings)

<sup>8</sup> The lack of certification in this study is because of building design; “not certified” buildings would qualify for some LEED points but not enough to achieve certification (see p.10). The data in this study does not contain green buildings that chose not to obtain official certification because of, for example, cost considerations. For more information, see Langdon, D., *The Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption*, 2007. <http://www.dladamson.com/USA/Research/ResearchFinder/2007-The-Cost-of-Green-Revisited/>

<sup>9</sup> DOE, Office of Energy Efficiency and Renewable Energy, “Whole Building Design for Commercial Buildings.” *Net-Zero Energy Commercial Buildings Initiative*. Updated 27 February 2009. [http://www1.eere.energy.gov/buildings/commercial\\_initiative/whole\\_building.html](http://www1.eere.energy.gov/buildings/commercial_initiative/whole_building.html)

<sup>10</sup> In a recent study, “green” commercial buildings were shown to have consistently higher market values than comparable “non-green” buildings. See Eichholtz, P., N. Kok, and J. M. Quigley, “Doing Well by Doing Good? Green Office Buildings.” *Berkeley Program on Housing and Urban Policy. Working Papers: Paper W08-001*, April 2008. [http://repositories.cdlib.org/iber/bphup/working\\_papers/W08-001](http://repositories.cdlib.org/iber/bphup/working_papers/W08-001).

<sup>11</sup> Brown, M., F. Southworth, and T. Stovall, *Towards a Climate-Friendly Built Environment* Prepared for the Pew Center on Global Climate Change, 2005. p17. [http://www.pewclimate.org/global-warming-in-depth/all\\_reports/buildings](http://www.pewclimate.org/global-warming-in-depth/all_reports/buildings)

<sup>12</sup> Brown, M., et al. 2005. [http://www.pewclimate.org/global-warming-in-depth/all\\_reports/buildings](http://www.pewclimate.org/global-warming-in-depth/all_reports/buildings);

Jones, D.B., D.J. Bjornstad, and L.A. Greer. *Energy Efficiency, Building Productivity, and the Commercial Buildings Market*. ORNL/TM-2002/107. Oak Ridge, TN: Oak Ridge National Laboratory, 2002. [http://www.cee1.org/eval/db\\_pdf/372.pdf](http://www.cee1.org/eval/db_pdf/372.pdf)